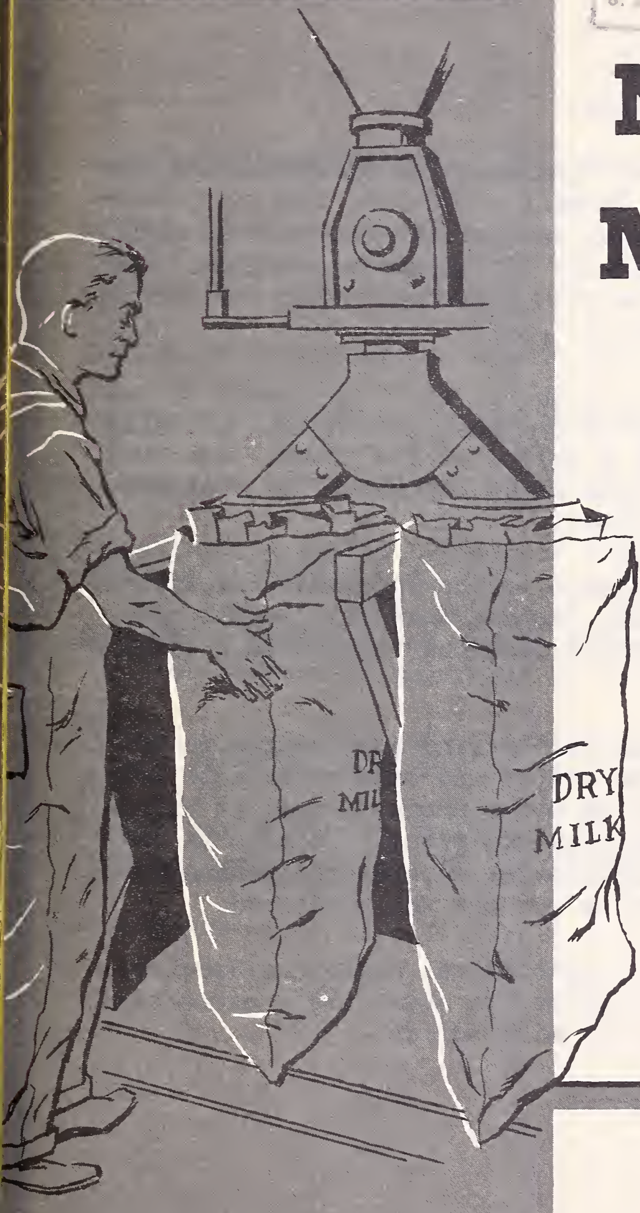
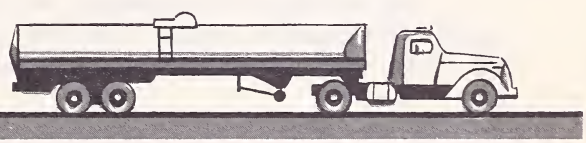
MARKETING RESEARCH REPORT NO. 126

Yield of NONFAT DRY MILK SOLIDS from a UNIT of MILK





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U. S. DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Marketing Research Division

PREFACE

The accuracy of the United States Department of Agriculture's marketing margin estimates is dependent largely on methods used in obtaining and utilizing data. For this reason part of the research on margins has been directed toward improving methods for measuring margins. That is the purpose of this report which is one of several reports on various phases of marketing margins and costs for food.

In determining margins for dairy products, it is necessary to calculate the quantity of farm milk used to produce a given unit of dairy product, such as a pound of butter or a gallon of ice cream. For this calculation, conversion factors are used which represent the average amount of milk used for a unit of product.

In the present report, data available to the Department of Agriculture have been analyzed to afford yield factors that will permit more accurate estimation of the amount of milk required to produce a given quantity of nonfat dry milk solids.

Yield factors for nonfat dry milk solids find application in the determination of margins published for butter and bakery products using nonfat dry milk solids and estimated for other products used in calculating the total margin for the dairy products group. It also is expected that they will be needed in calculating margins for consumers' sales of nonfat dry milk solids which as yet are not published.

Agricultural Estimates Division, Agricultural Marketing Service, also anticipates using the new yield factors to check their estimates of milk used in manufacturing nonfat dry milk solids.

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SUMMARY AND CONCLUSIONS

This study was designed to obtain more reliable measures of the yield of nonfat dry milk solids from a unit of milk to be expected under operating conditions and the approximate limits within which such yields could be expected to vary.

The average yield of nonfat dry milk solids found in this study was 8.16 pounds per 100 pounds of whole milk equivalent dried and 8.98 pounds per 100 pounds of liquid skim milk. Small differences in yields between roller and spray process plants and between plants receiving only whole milk and only skim milk were not statistically significant.

For the plants studied as a whole, variations in yields within individual plants were less than variations among plants.

The weighted average of the total solids in the liquid skim milk recovered in drying was 95.96 percent. This rate of recovery varied more greatly within plants than among plants. The proportion of the fat in the skim milk that was recovered varied widely.

Grading certificates for 400 lots of spray nonfat dry milk solids showed an average of 3.0 percent moisture in nonfat dry milk solids. The moisture in the nonfat dry milk solids analyzed in this study averaged 3.1 percent. This compares with a weighted average loss in drying of 4.04 percent of solids for the plants studied. Thus, on the average, losses of solids in drying were greater than the overrun in the powder due to retention of moisture.

The total solids content of the liquid skim milk to be dried was the most important factor affecting yield of nonfat dry milk solids. Yield per hundredweight of liquid skim milk varied on the average by 1.0026 pounds of powder for each change of 1.0 percent in solids content of the liquid skim milk. It could be expected that 95 percent yields, estimated from the regression would fall within 0.44 pound of the actual yield.

Because the butterfat and solids-not-fat content of whole milk are related, it is possible to estimate yield of nonfat dry milk solids directly from the butterfat content of the milk when the test of the cream separated from the milk is known. For 34 plant-days in this study, when 40 percent cream was separated from the whole milk, the yield per hundredweight of liquid skim milk varied on the average 0.4863 pound with each change of 1.0 percent in butterfat content of the whole milk. Under similar conditions, the estimated yield can be expected to fall within 0.414 pound of the actual yield in 95 percent of the cases.

YIELD OF NONFAT DRY MILK SOLIDS FROM A UNIT OF MILK 1/

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INTRODUCTION

Yield factors indicate quantities of milk products obtainable from unit quantities of milk. They are intended to represent average yields of products under normal operating conditions.

In the development of margin estimates, yield factors are necessary to determine the quantity of milk needed to manufacture a unit of a dairy product, so that retail and wholesale prices for the unit of product can be related to the farm price for an equivalent quantity of farm milk.

Yield factors are used extensively in the administration of Federal milk marketing orders; first, in pricing formulas and, second, in accounting for the utilization of milk. Yield factors are useful to plant managers as standards in appraising the efficiency of plant operations. They are also basic to the development of estimates relating to the utilization of milk.

The desirability of more research on the levels and variability of yield factors has been recognized. Information is needed on the ways in which yields of nonfat dry milk solids vary from lot to lot, from plant to plant, and possibly from region to region and season to season.

Available literature includes no comprehensive study of yields of nonfat dry milk solids. Yield data were developed incidentally rather than as the major purpose of the studies reported. Some of these data were estimates made by applying a fixed percentage of overrun to the solids-not-fat content of milk of various butterfat tests (2, 3, 13, 14, 15, 16, 17, 19 2/, table 1). In such estimates moisture content of the powder was assumed constant, butterfat content of the liquid skim milk and the powder were disregarded, and 100 percent recovery of solids in drying was assumed.

In other studies, yield data were obtained during detailed cost studies (11, 12, 14, 18, table 1). For various reasons these data are not comparable from study to study. They represent single trials or

1/ Data used in this study were gathered under the supervision of Frank A. Bele, Commodity Stabilization Service.
2/ Underlined figures in parenthesis refer to Literature Cited, pp. 18-19.

trials on a single drier. Accuracy of measurements, weights, and tests may not have been sufficiently well established; losses in the plant were not reported; solids content of the milk dried was not reported; etc.

Several reports give approximations of yields without giving sources of data, methods, causes of variations (6, 7, 8, table 1).

Table 1.--Yields of nonfat dry milk solids as reported in the literature

Source	Nonfat dry skim milk solids per 100 pounds of skim milk — Calculated theoretical yields	Yields reported as ranges	Yields consistent only within data studied
	Pounds	Pounds	Pounds
Literature citation:			
(2)	1/8.68		
(3)	2/8.69		
(6)		8.5 - 9.0	
(7)		8.5 - 9.5	
(8)		8.2 - 9.0	
(11)			8.5
(12) Roller 3/ ...			6.18 - 12.82
Spray 4/.....			7.16 - 10.32
(13)	1/8.70		
(14)			8.5
(15)	5/8.77		
(16)	8.68		
(17)	9.1		
(18) Roller			6/8.07
Spray			6/8.13
(19)	2/9.0		

1/ The yield per hundredweight of skim milk has been calculated from the yield per unit of whole milk reported in the reference cited.
2/ Whole milk contained 3.5 percent of butterfat.
3/ Range among 11 plants' average monthly yields.
4/ Range among 9 plants' average monthly yields.
5/ Yield from skim milk and buttermilk derived from 100 pounds of whole milk having 3.5 percent of butterfat.
6/ Average yield per 100 pounds of whole milk, fat content not stated.

Information on the distribution of yields which may be expected within the range is not available.

Hunziker (8, pp. 425-426) states: "The yield of milk powder depends principally upon the percentage of solids on the fluid milk product, the percentage of water in the dried product and the entrainment losses in

manufacture . . . The loss of milk solids ranges from a small portion of a percent to about 2 percent, averaging about 1 percent." Hunziker (7, p. 523) also mentions that the loss of milk solids ranges from 2 percent to 8 percent depending on the use of precondensing and the type of dust collector. Otherwise, practically no published information has been found that shows the range or distribution of moisture and fat content in nonfat dry milk solids or the percentage of solids that is lost in drying.

The present study was designed to obtain measures of the yield of nonfat dry milk solids from a unit of milk that may be expected when milk is dried under operating conditions, and the approximate limits within which the yields may be expected to vary.

PROCEDURES

Data for the study were obtained from 12 plants producing nonfat dry milk solids on 112 days. They were selected to represent the principal dairy sections of the United States in which milk powder is produced. A number of the plants were visited twice, once in fall or winter and once in spring or summer. The average length of plant visit was 5 days, during which weights and volume measurements were obtained and tests made of milk and products used and produced. The data were tabulated and analyzed in Washington, D. C.

Plant and Laboratory Procedure

The procedures for collecting weights and volume measurements, and methods of sampling, were developed on the basis of a pilot test in a multi-product plant.

The milk received was weighed at the receiving tank, or volume was measured at the holding tank. Yields were computed on the basis of the weight (or volume) of milk taken at the point nearest the processing operation. The total weight of all milk received was used as a check on the holding tank weights. The percentages of total solids and fat in the milk, cream, skim milk, and products were determined by the Mojonnier method. Percentages of solids-not-fat were obtained by subtracting the percentage of fat from the percentage of total solids. Aliquot samples were used for the total solids and fat tests. They were taken from each tank or vat weighed (or measured) or from each shipper's milk where individual shipper's weights were taken. The milk was thoroughly stirred before samples were taken. The samples were combined to make a composite sample representing each day's run. In whole milk operations, the weight of the skim milk dried was estimated as a residual by subtracting the weight of separated cream and milk used for other purposes from the weight of the whole milk received. Comparisons of yields from plants receiving only skim milk and plants separating whole milk and drying the separated skim milk indicated that this method of estimating the weight of the liquid skim milk was reasonably accurate.

Three cream samples were taken from each vat after pasteurization; one from each end and one from the middle of the vat. These cream samples were mixed and made into a composite sample.

Skim milk samples were taken every half hour during continuous operation of the plant.

Powder samples were taken from each barrel just prior to sealing. They were mixed to form a composite sample.

In addition to Mojonnier tests, Babcock tests were made of the milk and cream. Tests for fat and total solids were made on all products or partial products.

All tests were run in duplicate.

Yields of nonfat dry milk solids were calculated on the basis of the quantity of nonfat dry milk solids per unit of (a) whole milk, (b) actual liquid dried, and (c) total solids dried. The yields tests were made to determine whether differences in yields were statistically significant.

YIELDS PER 100 POUNDS OF LIQUID DRIED IN ALL PLANTS

The average yield of nonfat dry milk solids obtained from all runs in all 12 plants, regardless of qualifying factors, was 8.16 pounds of nonfat dry milk solids per 100 pounds of whole milk and 8.98 pounds per 100 pounds of liquid skim milk or skim milk equivalent (table 2).

Table 2.--Average yields of nonfat dry milk solids per 100 pounds of liquid milk

Type of plant	Yields of nonfat dry milk solids per hundred pounds of --			
	Whole milk		Skim milk equivalent	
	Plant days	Pounds	Plant days	Pounds
All types	59	8.16	112	8.98
Roller process plants	11	8.00	17	8.85
Spray process plants	48	8.20	85	8.98
Spray and roller plants	--	----	10	9.19
Plants receiving whole milk	--	----	59	9.02
Plants receiving skim milk	--	----	53	8.93

Yields in spray process plants averaged slightly higher than yields in roller process plants, but the difference was not statistically significant.

Plants drying only skim milk received from other plants had lower yields of nonfat dry milk solids than plants drying skim milk separated from whole milk received at the drying plant. However, these differences also were not statistically significant. (Table 2.)

On the whole, except for three midwestern plants, the plants studied showed more variation in yields among plants than from day to day within plants. 3/ Three midwestern plants had approximately the same yields.

Insufficient data were available to determine reliably whether differences in yields existed among areas or among seasons of the year.

RECOVERY OF SOLIDS IN DRYING SKIM MILK

In the literature, reference to the percentage of solids in the liquid skim milk that is recovered in nonfat dry milk solids is limited to the mention that small losses occur, and to pointing to the need for devices in spray dryers to recover smaller particles of milk powder from the exhaust air. It is possible that the overrun due to moisture content of nonfat dry milk solids has minimized the industry's attention to losses that occur in drying milk. The average moisture content of nonfat dry milk solids found in this study was 3.1 percent. This agrees closely with the 3.0 percent found in an analysis of the grading results on 400 lots of powder.

Table 3 shows that losses of total solids in drying are substantial and, on the average, greater than the gain in yield obtained from the moisture retained in the nonfat dry milk solids. The losses are of approximately the same magnitude in both spray and roller process plants, whether starting with whole milk or skim milk. The weighted average proportion of total solids recovered in this study was 95.96 percent.

Recovery of solids-not-fat also is fairly uniform among the various types of plants shown in table 3. However, the average proportion of fat recovered in this study varied significantly from plant to plant and varied significantly from day to day in some plants. There was no evidence available to show the extent to which these losses may have been more apparent than real, because of inaccuracies in tests or in measurements of the volume of liquid skim milk, or to other factors.

COMPOSITION OF NONFAT DRY MILK SOLIDS

Analyses of a number of samples of nonfat dry milk solids made in the early days of milk drying, 1904-1919, were reported by Hunziker (8, p. 529). Since then, technological developments and the growing experience of the industry with drying have made it possible to control the composition of nonfat dry milk solids more closely.

3/ These yields were adjusted for solids content of the skim milk before comparisons were made.

Table 3.--Recovery of solids in nonfat dry milk solids

Type of plant	Plant days	Solids-not-fat		Fat		Total solids	
		Weighted average	Range 1/	Weighted average	Range 1/	Weighted average	Range 1/
	Number	Percent	Percent	Percent	Percent	Percent	Percent
Spray; all plants	85	95.97	88.6-100.4	92.23	2/68.1-138.1	95.94	88.6-100.4
Skim	37	96.53	89.4-100.4	90.17	68.1-102.4	96.47	89.5-100.2
Whole	48	95.17	88.6-100.4	96.09	2/69.8-138.1	95.18	88.6-100.4
Roller; all plants	17	95.72	90.0- 99.7	97.83	74.8-124.7	95.74	90.0- 99.8
Skim	6	95.96	94.7- 97.6	100.15	83.4-112.4	96.00	94.7- 97.7
Whole	11	95.68	90.0- 99.7	97.46	74.8-124.7	95.69	90.0- 99.8
Spray-roller; skim	10	96.55	94.3- 98.6	95.32	89.4-111.6	96.54	94.2- 98.6
All skim plants ..	53	96.52	89.4-100.4	91.07	68.1-112.4	96.47	89.5-100.2
All whole milk plants	59	95.27	88.6-100.4	96.44	2/69.8-138.1	95.28	88.6-100.4
All plants	112	95.99	88.6-100.4	93.09	2/68.1-138.1	95.96	88.6-100.4

1/ An unknown part of the ranges shown above is due to sampling error, variability in estimating or measuring the volume of liquid skim milk, and the possible variability inherent in the Babcock and Mojonnier tests.

2/ One fat recovery figure, 566.22 percent, was omitted from the range because the sample of liquid skim milk appeared to be faulty.

The tendency has arisen for users of nonfat dry milk solids to demand powder that meets definite specifications. The United States Department of Agriculture has established grade standards for nonfat dry milk solids which, in turn, except for requiring a lower moisture content, were adopted by the Commodity Credit Corporation for its purchases of nonfat dry milk solids. Since these purchases have amounted roughly to one-third of U. S. production since 1947, undoubtedly the U. S. Department of Agriculture's grade standards have affected the average composition of nonfat dry milk solids produced in the United States.

USDA grading and inspection records for 400 lots of spray process nonfat dry milk solids were analyzed to determine the average and range of moisture, fat, solids-not-fat, and total solids to be expected in nonfat dry milk solids. 4/ Each season of the year, December 1954 to November 1955, was represented by 100 lots in 1 month per season. Table 4 shows the result of the analyses.

Table 4.—Composition of nonfat dry milk solids, shown by 112 days of operation and by 400 lots graded by U. S. Grading Service

Component of powder	112 days in 12 plants			400 lots graded by USDA		
	Average	Standard deviation	Range	Average	Standard deviation	Range
	Percent	Percent	Percent	Percent	Percent	Percent
Total solids	96.91	±0.486	95.95-98.00	96.97	±.368	94.8-98.0
Solids-not-fat	96.09	±0.510	94.86-97.22	96.24	±.400	94.2-97.2
Fat	0.82	±0.188	0.49-1.56	0.73	±0.162	0.50-2.41
Moisture	3.10	±0.492	2.00-4.05	3.03	±0.368	2.0-5.2

Analyses of the lots of nonfat dry milk solids in the present study yielded similar results. (Table 4.)

THE EFFECT OF SOLIDS CONTENT OF SKIM MILK ON YIELD OF NONFAT DRY MILK SOLIDS

When comparisons of yields were made between, among, and within various groupings it became obvious that differences in the yield of nonfat dry milk solids were directly related to differences in the solids content of the milk dried.

4/ Only 1 small lot of roller process powder was observed in selecting the sample of 400 lots. It was not included in the sample. Low-heat roller process powder might be expected to contain more moisture than spray process powder.

In addition to skim milk solids, the percentage of total solids recovered in the nonfat dry milk solids and the composition of the nonfat dry milk solids also varied. Therefore, these factors also might be expected to affect yield. However, the relationship between these latter two variables and yield was found to be so small that including them with total solids to estimate yield did not improve the estimate obtained from solids alone.

On the average, the yield of nonfat dry milk solids increased 1.0026 pounds for each 1.0 percent of increase in total solids content of the liquid skim milk (fig. 1).

This estimate of yield for a single day's run is subject to a standard error of estimate of ± 0.22 pounds of nonfat dry milk solids. Thus, in repeated daily runs, 95 percent of the yields from 100 pounds of skim milk with 9.08 percent total solids would be expected to fall in a range 2 times the standard error, or 8.54 pounds to 9.42 pounds of nonfat dry milk solids, with an average of 8.98 pounds.

In testing for the significance of differences in yields, allowances were made for the relationship between yield and total solids content of the liquid skim milk.

ESTIMATING THE YIELD OF NONFAT DRY MILK SOLIDS FROM THE TOTAL SOLIDS CONTENT OF SKIM MILK

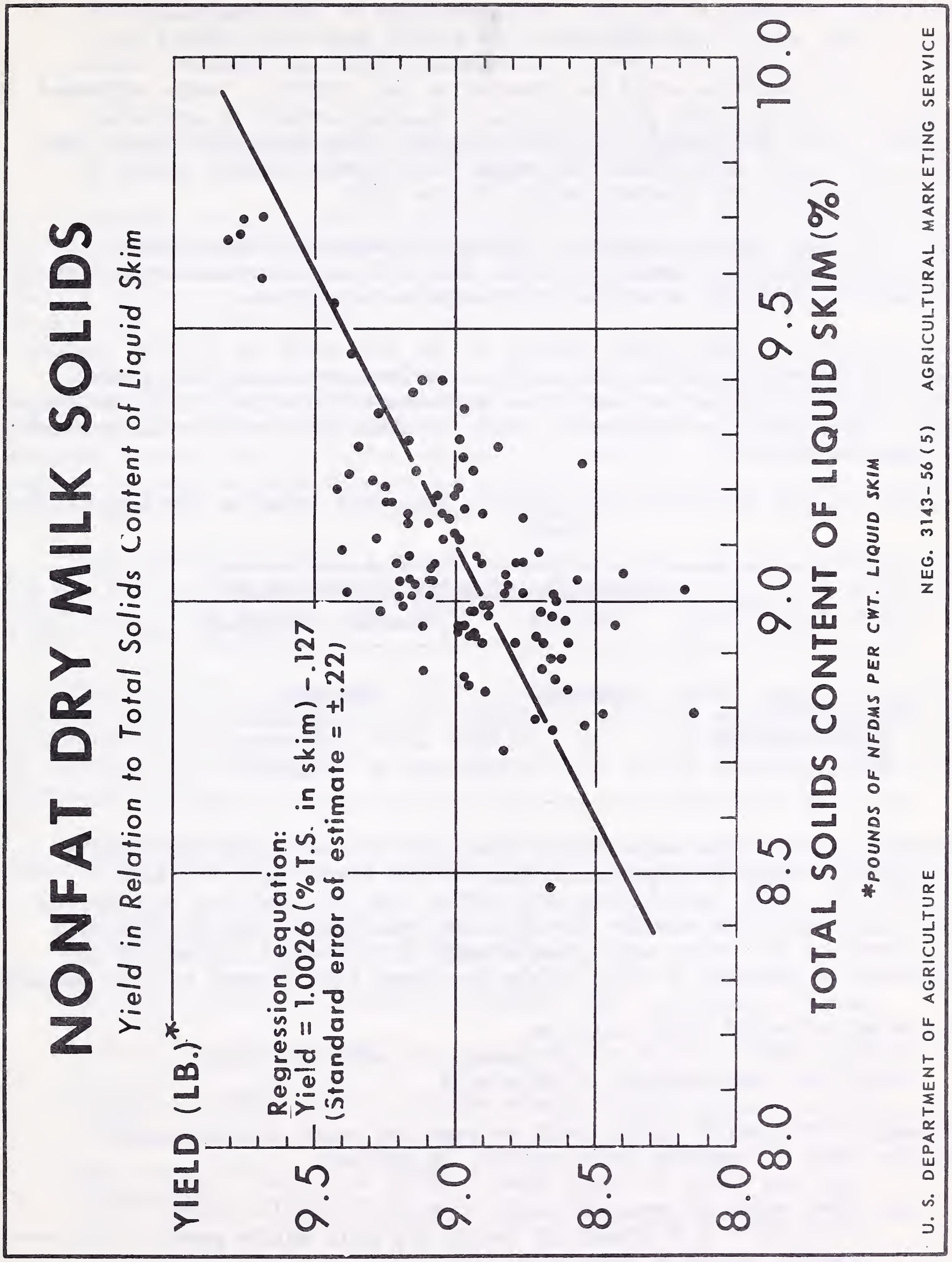
This relationship between the total solids content of skim milk and yield of nonfat dry milk solids is a fundamental cause of variation in yields per unit of milk.

It is obvious that more solids cannot be obtained in the nonfat dry milk solids than are present in the liquid milk. Similarly it is apparent that the solids in the skim milk that is dried should be found in the nonfat dry milk solids, with some allowance for loss.

For this reason, results of tests showing the solids content of skim milk used in the given plant are needed to determine with reasonable accuracy what yields of nonfat dry milk solids to expect.

The regression equation for figure 1, yield = $-0.127 + 1.0026$ (total solids test of skim milk) ± 0.22, can be used to make estimates based on total solids content of skim milk or the yield can be read directly from figure 1. The calculation from the equation is as follows:

Where the total solids content of skim milk is, say, 9.08 percent, average yield = $(9.08)\ (1.0026) - 0.127 = 8.98$ pounds of nonfat dry milk solids per hundred pounds of skim milk.



NONFAT DRY MILK SOLIDS
Yield in Relation to Total Solids Content of Liquid Skim
YIELD (LB.)*
9.5
9.0
8.5
8.0
Regression equation:
Yield = 1.0026 (% T.S. in skim) -.127
(Standard error of estimate = ±.22)
8.0
8.5
9.0
9.5
10.0
TOTAL SOLIDS CONTENT OF LIQUID SKIM (%)
*POUNDS OF NFDMS PER CWT. LIQUID SKIM
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Figure 1

Because the recovery of solids, the composition of the skim milk, etc., vary among plants, yield is predictable with a high degree of reliability only within a range about the average calculated yield. In repeated trials, 95 percent of the estimates would be expected to fall within a range expressed by the expected average yield plus or minus 2 standard errors of estimate; in the present case, 8.98 pounds $\pm 2(0.22)$ pounds. Thus one could expect that the actual yield would fall within the range, 8.76 pounds to 9.20 pounds of nonfat dry milk solids per hundred pounds of skim milk.

Since the total solids content of skim milk frequently has not been determined some estimate of total solids in skim milk may be necessary before the yield can be calculated according to the above regression.

When neither the total solids content of the skim milk nor the fat content of the whole milk from which the skim milk is derived are known, the average composition of skim milk can be used as an estimate of total solids in the skim milk dried. The average percentage of solids in skim milk found in the present study is shown in table 5.

Table 5.--The average percentage of solids in skim milk dried on 112 days in 12 plants

Kind of solids	Proportion of solids in skim milk	
	Average	Standard deviation
	Percent	Percent
Total solids ...	9.08	±0.208
Solids-not-fat	9.00	±0.213
Fat	0.08	±0.020

From skim milk of this composition, the yield of nonfat dry milk solids can be calculated using the regression equation for figure 1, $y = -.1273 + 1.0026\,x \pm 2(.22)$. This calculation will differ from the previous calculation because one must take into account the fact that the composition of skim milk may vary. Based on the above table, the average total solids content of the skim milk would be expected to fall within the range 8.66 percent to 9.50 percent.

The average expected yield would be,

$(9.08)(1.0026) - 0.127 = 8.98$ pounds of nonfat dry milk solids per hundredweight of skim milk

The range within which yields could be expected would be calculated from the range of expected total solids, as follows:

(a) Lower range of expected yield $= (8.66)(1.0026) - 0.127 - 2(0.22) = 8.12$ pounds of nonfat dry milk solids per hundred pounds of skim milk

(b) Upper range of expected yield = (9.50) (1.0026) - 0.127 +2(0.22) = 9.84 pounds of nonfat dry milk solids per hundred pounds of skim milk.

ESTIMATING THE YIELD OF NONFAT DRY MILK SOLIDS FROM THE BUTTERFAT CONTENT OF WHOLE MILK

Occasions arise in which the butterfat content of the whole milk, but not the solids content of the skim milk, is known. The fact that the solids-not-fat and butterfat content of milk vary in the same direction suggested that it might be feasible to estimate yield of nonfat dry milk solids directly from the butterfat content of whole milk (1, 4, 5, 9) 5/.

This hypothesis was tested by a regression analysis covering 34 plant-days of drying in which the whole milk was separated into 40 percent cream and skim milk and the skim milk was dried. The whole milk covered in this analysis tested from 3.5 to 4.1 percent of butterfat. The analysis was limited to these 34 days because the proportion of solids-not-fat recovered in skim milk varies with the fat content of the cream.

This regression analysis showed an average yield of 8.93 pounds of nonfat dry milk solids per hundred pounds of liquid skim milk, with the standard deviation, ± 0.224 pounds. The resultant regression equation was: Yield = $7.065 + 0.4863 \pm 0.207$.

Thus, on the average, the yield would increase 0.4863 pound of nonfat dry milk solids per 100 pounds of liquid skim milk for each 1.0 percent rise in butterfat content of the whole milk (fig. 2). In repeated trials, in 19 of 20 times the yield would be expected to fall within 2(0.207) pound of the calculated yield.

For this method of estimating the yield of nonfat dry milk solids from whole milk, yield would be calculated according to the following equation:

Yield in pounds of NFDMS per cwt. of skim milk = [(Butterfat test of whole milk) (0.4863) + 7.065] ± 0.414.

For milk testing 4.0 percent butterfat, the calculation follows:

[(4.0) (0.4863) + 7.065]

(1.9451 + 7.065) = 9.01 = average expected yield percent of skim milk

9.01 - 0.414 = 8.60 lbs. NFDMS = lower limit of yield per cwt. skim milk

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5/ Extensive lists of references on the relationship between the solids-not-fat and fat in milk are available. See (4, 5).

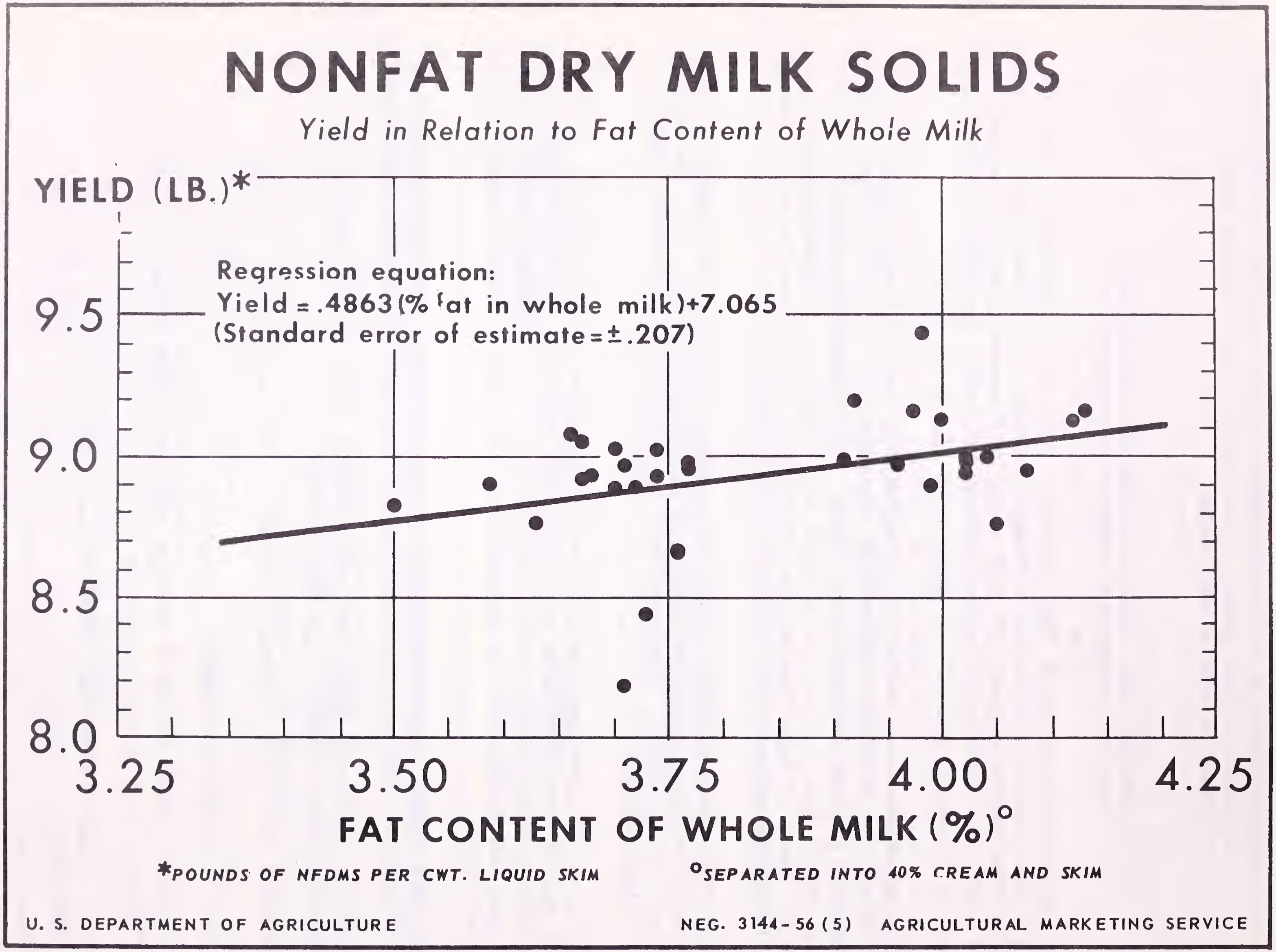
NONFAT DRY MILK SOLIDS
Yield in Relation to Fat Content of Whole Milk
YIELD (LB.)*
Regression equation:
Yield = .4863 (% fat in whole milk)+7.065
(Standard error of estimate = ±.207)
9.5
9.0
8.5
8.0
3.25
3.50
3.75
4.00
4.25
FAT CONTENT OF WHOLE MILK (%)°
*POUNDS OF NFDMS PER CWT. LIQUID SKIM
°SEPARATED INTO 40% CREAM AND SKIM
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Figure 2

$9.01 + 0.414 = 9.42$ lbs. NFDMS = upper limit of yield per cwt. skim milk

These calculations have been used in Method B, table 6.

Estimates of yields for milk testing below 3.5 percent or above 4.1 percent can be made using this method because the relationship between solids-not-fat and fat is linear or nearly so (5, 9, 10). However, beyond the range of fat content, 3.5 percent to 4.1 percent, uncertainty is increased and the range of estimates within which yields should be expected to fall would widen slightly as the extrapolation moves away from the range, 3.5 percent to 4.1 percent.

COMPARISON OF YIELDS BASED ON TOTAL SOLIDS IN THE SKIM MILK AND ON BUTTERFAT CONTENT OF WHOLE MILK

In table 6, the ranges of expected yields are shown for milk testing from 3.0 percent to 5.0 percent butterfat. These ranges have been calculated on the basis of: (a) Total solids in the skim milk from the milk of the various tests and the relationship between total solids in skim milk and yield as determined previously (fig. 1, p. 10); and (b) the relationship between butterfat content and yield of nonfat dry milk solids (fig. 2, p. 13).

The average estimate of yield for milk of a given fat test is approximately the same by both methods. However, the limits within which the actual yield could be expected are much more narrow for the estimate based on fat content than that based on total solids content of skim milk.

Differences in the confidence limits of the two estimates are caused by two major reasons: (a) The fact that the group of 34 plant-days used to calculate Method B have more similar characteristics than the 112 plant-days used to determine Method A. This homogeneity results in a smaller standard error of the regression equation for Method B than for Method A. (b) The range of total solids content of skim milk used for Method A is wider than that found for the 34 plant-days used for Method B (tables 6 and 7). When the total solids content of the 34 plant-days is used with Method A to calculate yield, the ranges of expected yields are in close agreement with ranges calculated by Method B (table 7).

The fact that the basic factor affecting yields is the total solids content of the skim milk suggests that more reliable estimates of the range of expected yield can be obtained by Method A than by Method B. Further, Method A is based on a larger amount of data and is likely to more nearly represent general conditions than Method B.

Table 6 can be used directly to read expected yields for a given fat test by either method. In verifying usage or determining yields under conditions where the total solids content of the skim milk is unknown, yields within the range of estimate shown by Method A would be in accord with the ranges of total solids known to occur in milk.

Table 6.—Range of expected yields of nonfat dry milk solids per hundred pounds of skim milk 1/

Butterfat test of whole milk	(1) Average solids-not-fat in whole milk 2/	(2) Average solids-not-fat recovered in skim milk 3/	(3) Estimated total solids in skim milk 4/	(4) Estimated range of total solids in skim milk 5/	Yield of NFDMS per cwt. of skim milk: Method A, based on total solids in skim milk 6/		Method B, based on fat in whole milk 8/	
					Average	Range 7/	Average	Range 7/
Percent	Percent	Percent of whole milk	Percent	Percent	Pounds	Pounds	Pounds	Pounds
3.0	8.35	7.88	8.58	8.25- 8.91	8.48	7.70- 9.25	8.52	8.11-8.94
3.1	8.39	7.92	8.65	8.32- 8.98	8.54	7.77- 9.32	8.58	8.16-8.99
3.2	8.44	7.96	8.68	8.38- 9.04	8.60	7.83- 9.38	8.62	8.21-9.04
3.3	8.48	8.00	8.78	8.45- 9.11	8.68	7.90- 9.45	8.67	8.26-9.08
3.4	8.52	8.04	8.85	8.52- 9.18	8.74	7.97- 9.52	8.72	8.30-9.13
3.5	8.56	8.08	8.92	8.59- 9.25	8.82	8.05- 9.59	8.76	8.35-9.18
3.6	8.61	8.12	8.99	8.66- 9.32	8.89	8.12- 9.66	8.82	8.40-9.23
3.7	8.65	8.16	9.05	8.72- 9.38	8.95	8.18- 9.72	8.86	8.45-9.28
3.8	8.69	8.20	9.12	8.79- 9.45	9.02	8.25- 9.79	8.92	8.50-9.33
3.9	8.74	8.25	9.20	8.87- 9.53	9.10	8.33- 9.87	8.96	8.55-9.38
4.0	8.78	8.28	9.26	8.93- 9.59	9.16	8.39- 9.93	9.01	8.60-9.42
4.1	8.82	8.32	9.33	9.00- 9.66	9.23	8.46-10.00	9.06	8.64-9.47
4.2	8.87	8.37	9.41	9.08- 9.74	9.31	8.54-10.08	9.10	8.69-9.52
4.3	8.91	8.41	9.48	9.15- 9.81	9.38	8.61-10.15	9.16	8.74-9.57
4.4	8.95	8.45	9.56	9.23- 9.89	9.46	8.69-10.23	9.20	8.79-9.62
4.5	9.00	8.49	9.63	9.30- 9.96	9.53	8.76-10.30	9.26	8.84-9.67
4.6	9.04	8.53	9.70	9.37-10.03	9.60	8.83-10.37	9.30	8.89-9.72
4.7	9.08	8.57	9.77	9.44-10.11	9.68	8.90-10.45	9.35	8.94-9.76
4.8	9.12	8.61	9.84	9.51-10.17	9.74	8.97-10.51	9.40	8.99-9.81
4.9	9.17	8.65	9.92	9.59-10.25	9.82	9.05-10.59	9.44	9.03-9.86

1/ Assuming separation of whole milk into 40 percent cream and skim milk.

2/ From the regression equation determined for 59 plant days in this study: Percentage of solids-not-fat in whole milk = 7.060 + .430 (percent of fat) $\pm$0.17.

- Continued

Table 6.--Range of expected yields of nonfat dry milk solids per hundred pounds of skim milk 1/-Con.

3/ Column (1) multiplied by 94.36 percent, the average proportion of solids-not-fat in the whole milk recovered in the skim milk on 59 plant days in this study. The standard error of the recovery percentage is ± 0.33 percent.

4/ Column (2) divided by pounds of skim milk resulting from separating whole milk into 40 percent cream and skim milk. To this result was added 0.08 pound butterfat, the average fat content of the skim milk for 112 plant days in this study. The standard error of this average fat is ± 0.002 percent.

5/ Calculated from Column (3) by adding and subtracting two standard errors or ± 2 (0.163). The standard error was computed from the combined variances of the estimates in Columns 1 and 2, assuming no correlation between factors, according to the formulas:

(a) Variance of estimated solids-not-fat, (Col. 1 x average recovery rate) = (Variance, Col. 1)(Variance, recovery rate)+(Av. of Col. 1)^2(Variance, recovery rate) +(Av. recovery rate)^2(Variance, Col. 1)

(b) Variance of estimated total solids, (Est. solids-not-fat + av. fat in skim milk) = Variance computed in (a) + Variance of average fat

$$\text{Standard error of estimate} = \sqrt{\text{Variance computed in (b)}} = \pm .163$$

6/ See page 10, fig. 1.

7/ Ranges have been calculated to include 2 standard errors in each direction from the expected averages, or approximately 95 percent of yields which would be expected in repeated trials.

8/ See page 13, fig. 2.

Table 7.—Yields of nonfat dry milk solids as estimated from the fat in the whole milk and from the solids in skim milk separated from the same whole milk, 34 plant days

Number of days	Fat in whole milk	Total solids in skim milk	Yield per hundred pounds of skim milk			
			Estimated from total solids in skim milk 1/ (Method A)		Estimated from fat in whole milk 2/ (Method B)	
			Average 3/	Range 4/	Average	Range
	Percent	Percent	Pounds	Pounds	Pounds	Pounds
1	3.5	9.04	8.94	8.50-9.38	8.76	8.35-9.18
2	3.6	9.01-9.07	8.94	8.47-9.41	8.82	8.40-9.23
12	3.7	8.83-9.17	8.90	8.29-9.51	8.86	8.45-9.28
4	3.8	8.84-8.97	8.80	8.30-9.31	8.92	8.50-9.33
2	3.9	9.01-9.11	8.96	8.47-9.45	8.96	8.55-9.38
10	4.0	9.15-9.55	9.25	8.61-9.89	9.01	8.60-9.42
3	4.1	9.08-9.40	9.14	8.54-9.74	9.06	8.64-9.47

1/ Y = (T.S. in skim)(1.0026) - 0.127 ±2(0.220).
2/ Y = (fat in whole milk)(0.4863) + 7.065 ±2(0.207).
3/ Calculated from the midpoint of the range of total solids in the skim milk.
4/ Calculated from the low total solids figure and the high total solids figure, plus or minus 2 standard errors.

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